cially as depths of snow have increased substantially dur ing the general snowstorm occurring the first week in April.—*R. Q. Grant, Section Director.*

*South Dakota.*—The average snowfall in the elevated regions of South Dakota; that is, the greater portion of the Black Hills district of the State, was 7 inches. The largest monthly amount recorded was 23 inches, at Harvey's ranch (P. O. Hanna), Lawrence County; the least 0.2 inch at Hermosa, Custer County. There was none remaining on the ground on either the 15th or 31st of the month, except in the gulches in the timber. Some of the snow melted as it fell, or soon after, and thawing weather with local showers near the close of the month aided in its disappearance.—*S. W. Glenn, Section Director.*

*Nevada.*—There was scarcely any snow or precipitation in the Truckee, Carson, and Walker Basins during March. The average for 12 stations in the Humboldt Basin was 0.43 of an inch, which was only about one-third of the normal. This is representative of the northern portion of the State.

At the Lake Tahoe level there were about 39 inches of dense snow at the end of the month, and it increased in depth from that point to 137 inches at the 7,400-foot level, just south of Ward Peak. There were from 96 to 120 inches near Grass and Luceil Lakes at an elevation of about 8,000 feet. East of Lake Tahoe there were about 84 inches at 8,000 feet. In the Carson and Walker Basins on nearly all northwest, north, and northeast slopes, above 9,000 feet, there were over 260 inches of snow at the end of March.—*H. S. Cole, Section Director.*

*Arizona.*—March was a warm, dry month in the eastern and northern mountain districts, and there was a general decrease in the depth of stored snow.

In the White Mountains, where a survey of a representative area was made, March 21 to 27, the snow on the north slopes ranged from a trace at the 8,000-foot level to about 50 inches at the 10,000-foot, while on the south slopes there was but little snow below 9,000 feet, and at 10,000 feet the depth was about 15 inches. The extensive flats of high elevation, situated along the Salt-Little Colorado Divide, held from 20 to 30 inches of snow. The average of a large number of density measurements gave an equivalent of 0.33 inch of water for 1 inch of snow.

Reports indicate that the snow conditions on the Blue, Graham, and San Francisco Ranges are about the same as in the White Mountains, while on the Chiricahuas the depths are somewhat less. There is little or no snow left in the Tonto and East Verde watersheds. Drifts from 2 to 4 feet deep remain on the plateaus north of the Colorado River. A few inches remain on the Huachuca Mountains.—*Robert R. Briggs, Section Director.*

*New Mexico.*—March averaged much below the normal in precipitation, although the snowfall was parctically normal, owing to heavy snow in certain central and northern mountain districts, notably east of the Rio Grande. For the State as a whole the eastern slopes were most favored.

The average snowfall was 3.8 inches, or about normal, giving a seasonal fall of 26 inches, which is slightly in excess of the normal, owing to the large excess that occurred in December, 1913.—*Charles E. Linney, Section Director.*

*Colorado.*—The snowfall during March was less than the normal in almost all parts of the mountain region, making the third month in succession with relatively light amounts. Storms were not lacking, but precipitation was general only during the last three days of the month.

On the middle drainage of the South Platte and in the region drained by the southern tributaries of the Arkansas somewhat more than the normal snowfall occurred, but in the rest of the drainage area of these streams a deficiency was general. Marked deficiencies occurred throughout the region drained by the Rio Grande, and and over the greater part of the Grand, Gunnison, and San Juan watersheds.

The average depths of snow on the ground on the different watersheds at the end of the month do not differ materially from the depths on corresponding date a year ago; the water equivalent, however, is greater.—*F. H. Brandenburg, District Forecaster.*

## POSSIBILITY OF RECURRENCE OF THE FLOODS OF MARCH, 1913.

By J. WARREN SMITH, Professor of Meteorology.

[Dated Weather Bureau, Columbus, Ohio, March 12, 1914.]

[Abstract of a paper read March 11, 1914, at the Thirty-fifth annual meeting of the Ohio Engineering Society, held at Columbus, Ohio.]

During the past 20 years the number of coöperative stations in Ohio reporting rainfall has varied but little and has been slightly over 100 in number.

The number of times that excessive rains have occurred at these different points has been tabulated and the summary appears in Table 1.

This table shows that while the number of stations reporting 2.5 inches in 24 hours in 1913 was less than twice as many as reported this amount in 1896 and 1897, and only just twice as many as in 1911, the number reporting 5.0 inches or more in 96 hours in 1913 was more than in all of the other 19 years put together.

In March, 1913, the number reporting 5.0 inches or more in 96 hours was 73, while during all of the other months of the 20 years together the number was only 69.

In October, 1910, there was a very heavy and extended rainfall in Ohio that gave 2.5 inches or more in 24 hours at 35 stations, 3.0 inches or more in 48 hours at 49 stations, and 4.0 inches or more in 72 hours at 31 stations; or about half as many as occurred in March, 1913. But in October, 1910, there were only 3 cases of 4.0 inches or more in 24 hours, as compared with 13 in March, 1913, and only 3 stations reporting 5.0 inches or more in 96 hours, as compared with 73 reporting this amount in March, 1913.

It is only when one begins to tabulate the facts in this way that the statement can be understood that when the extent of the territory involved and the sequence of the storms is considered, no previous record exists which, in this section of the country, is in any way comparable with the rainfall of March 23–27, 1913.

The greatest monthly rainfall for the State of Ohio during the past 60 years was 9.67 inches, in September, 1866. The next greatest monthly average was 8.40 inches, in March, 1913. The daily records for such stations as were available in 1866 show, however, that during that month the rainfall was distributed more through the month and that large monthly falls were due to a number of scattered heavy rainfalls.

A careful summary of the rainfall data in Ohio for March, 1913, shows that the average rainfall from the 23d to 27th, inclusive, was as follows:

| | Inches. |
|---|---|
| Over the Little Miami watershed | 7.5 |
| Over the Sandusky watershed | 8.2 |
| Over the Scioto watershed | 8.7 |
| Over the Great Miami watershed above Dayton | 8.6 |
| Over the Muskingum watershed above Zanesville | 6.9 |

TABLE 1.—*Number of stations in Ohio reporting excessive rainfall in the year indicated.*

| Year. | 2.5 inches or more in 24 hours. | 4 inches or more in 24 hours. | 3 inches or more in 48 hours. | 4 inches or more in 72 hours. | 5 inches or more in 96 hours. | 10 inches or more in 1 month. |
|---|---|---|---|---|---|---|
| 1894 | 15 | 2 | 5 | 1 | 0 | 0 |
| 1895 | 13 | 0 | 10 | 0 | 0 | 0 |
| 1896 | 58 | 6 | 52 | 27 | 13 | 17 |
| 1897 | 59 | 7 | 32 | 13 | 5 | 3 |
| 1898 | 38 | 4 | 38 | 17 | 11 | 4 |
| 1899 | 20 | 5 | 7 | 0 | 0 | 0 |
| 1900 | 22 | 0 | 11 | 0 | 0 | 0 |
| 1901 | 45 | 5 | 38 | 25 | 11 | 2 |
| 1902 | 34 | 4 | 55 | 28 | 4 | 6 |
| 1903 | 34 | 5 | 28 | 10 | 4 | 0 |
| 1904 | 34 | 2 | 40 | 16 | 3 | 0 |
| 1905 | 45 | 5 | 37 | 8 | 3 | 1 |
| 1906 | 26 | 2 | 17 | 5 | 2 | 2 |
| 1907 | 43 | 5 | 48 | 19 | 2 | 3 |
| 1908 | 23 | 1 | 10 | 0 | 0 | 0 |
| 1909 | 45 | 8 | 25 | 7 | 0 | 1 |
| 1910 | 49 | 3 | 65 | 34 | 6 | 0 |
| 1911 | 54 | 3 | 18 | 4 | 0 | 0 |
| 1912 | 45 | 1 | 24 | 6 | 0 | 0 |
| 1913 | 108 | 21 | 106 | 84 | 78 | 31 |
| Sums | 810 | 89 | 666 | 304 | 142 | 70 |
| Means | 40 | 4 | 33 | 15 | 7 | 4 |

*Probability of similar heavy rainfalls in future.*

The preceding statements show that while the rainfall in March, 1913, was unprecedented in duration, intensity, and area covered so far as the central part of the United States is concerned, yet the atmospheric conditions that produced the rainfall were apparently not abnormal.

And further, that there is nothing to prevent the same atmospheric conditions recurring any time, and hence no good grounds for not saying that we may have the same or a more severe rainfall at any time in the future.

On the other hand there seems no basis whatever for the statement in the local press of February 10, accredited to the president of the National Drainage Congress, that—

> There is a scientific reason to expect a flood this year that may be as disastrous as that of 1913.

The newspaper clipping indicates that the reason for this statement is the fact that there was a deficiency in rainfall in January in the Mississippi and Ohio valleys, and thus:

> An abnormal rainfall equal to that of 1913 is to be expected in order to bring the precipitation up to normal, according to the records of the drainage commission.

It is true that there was a deficiency in rainfall in January in most of the Mississippi and Ohio valleys and that this deficiency amounted to over 4 inches in the vicinity of Vicksburg, Miss., but it is not true that similar deficiencies are immediately followed by excessive precipitation or that a monthly rainfall above the normal will necessarily cause floods.

A careful correlation has been made between the rainfall in January and that in March in Ohio, during the past 60 years, and this shows a correlation coefficient of 0.24. This means that when the rainfall is deficient in January it is most apt to be deficient in March also, and when the rainfall is in excess in January it is most apt to be wet in March.

And not only this, but in the past 60 years there never have been but two years when a very dry January in Ohio has been followed by a rainfall of more than 1 inch above the normal in either February, March, or April in Ohio. And further, during the past 50 years a very dry January has been followed by rainfall enough in either February, March, or April to cause even one day of flood at Cincinnati only four times.

The January just past had an average rainfall almost 1 inch below the normal in Ohio, but instead of this being a condition favorable for later floods, as stated in the newspaper article referred to, it is just the opposite. Hence the probability of floods in Ohio this spring is much less than if the rainfall in January had been above the normal.

The heaviest rainfall in one day in Ohio that has ever been recorded was 7.4 inches at Toboso, in northeastern Licking County, on the night of July 13, 1913. This storm was very severe, and while it gave heavier 12- and 24-hour rainfalls at a few places than occurred in the March storm, it was not of so large an area and was not followed by successive downpours.

It shows, however, as do other storms that might be cited, that there is nothing to prevent a recurrence of the heavy rainfall of last March in any section of the country. On the other hand the fact that no such extended and continuous rainfall has occurred before in Ohio during the past 60 years at least, and probably not during the past 100 years, must lead to the conclusion that the chances are against a repetition of such a rain within the next 60 or 100 years.

*Probability of similar flood damage with same rainfall.*

The ground was not frozen at the beginning of the heavy rainfall in March, 1913, but sufficient rain had fallen only two days before to thoroughly saturate the soil, so that when the heavy rain began the streams felt its influence immediately. Floods will occur when there is an excessive rainfall or with a combination of heavy rainfall and melting snow.

The encroachments on the streams, both in the matter of fills and in low and short bridges, intensified the flood damage at places on all of the streams, but the cause of the unprecedented high water was the unprecedented rainfall and nothing else.

In WEATHER BUREAU BULLETIN No. 40 the writer has correlated the rainfall over the Ohio watershed above Cincinnati with the river-gage readings at that place for the 50 years from 1861 to 1910, inclusive. This shows that, with the same rainfall, the tendency for high water and floods is not quite so great during the last half of that period as during the first half. A tabulation of the rainfall and river heights for each 10 years shows without question that floods are not increasing at Cincinnati with the same rainfall.

The correlation of low water and rainfall in this bulletin shows that, with the same rainfall, the number of days with the river below 10 feet will not be so great now as was experienced 30 or 40 years ago.

*Conclusions.*

The conclusions drawn from this paper and other studies regarding the rainfall and stream flow are:

1. Excessive rainfalls in the interior of the United States are due to unstable atmospheric conditions that accompany some low-pressure areas as they move across the country from west to east.

2. Usually these conditions of heavy rain are of short duration and comparatively small area and progress eastward with the depression. Occasionally, however, when the depression stands nearly still or when a southwest-

northeast trough forms and two or more disturbances follow each other rapidly, each accompanied by heavy rain, the area of excessive rain is enlarged, and the total rainfall causes serious floods.

3. Floods are due to excessive rainfall. While the draining of the swamps, the tiling of the fields, and the cutting of the forests may have some slight effect upon the intensity of the flood, all these things are of far secondary importance when compared with the rainfall.

The combination of the meteorological factors which caused the flood of March, 1913, may recur any year, but the probability of a repetition is not great. It is true that the duration and area of the intense rainfall in last March never has been approached before in the history of meteorological records in Ohio and probably not in any other district in this part of the country.

The tendency for excessive rains to occur is not growing greater. Neither are floods growing more frequent or are they worse with the same rainfall.